Physics 419: Lecture 1
January 18:

Basic questions:

1.) What is it to have knowledge of the world?

2.) What are the grounds and limits of our ability to know?

3.) What is really the case about the world around us?

4.) What distinguishes knowledge from opinion?

The ancient Greek philosophers set out to answer these questions. The ancient Greeks had two tools at their disposal: 1) pure reason and 2) generalization based on observation. They noticed that statements about the geometrical relationship between objects were not as subject to change as statements about nature itself, for example on what is the most basic substance. Why? Geometrical claims are established by pure logical reasoning. Statements about nature require some body of knowledge that may be fallible; strictly speaking it is not knowledge if it is fallible. Hume claimed that any knowledge that has any content, that is non-tautological, cannot be based on pure reason. That is, knowledge must be based on empirical observation. Hence, either mathematical statements reflect something about the world or they are known by pure reason. But they cannot be both if Hume is correct. Kant countered that knowledge claims do not require empirical observation for them to have content. He advocated that a class of knowledge claims known as *a priori* synthetic statements exist which although are knowable from experience can be established with pure reason alone. Certain geometrical statements such as the sum of the interior angles of a triangle is 180 degrees does not follow from any definition of a triangle but depends on the space itself. Bachelors are unmarried is a quite different type of statement. Kant argued that geometry and arithmetic provide ample evidence that knowledge claims do not requrie empirical backing. Both contain statements that are indpendent of experience and contain content. Hence, Hume must be wrong. These issues will be in the background as we discuss theories of space time and matter throughout this class.

Our focus in this class is the scientific theories of space, time, and matter and the philosophical problems they pose. While all scientific theories focus on some aspect of space, time, or matter, we will be concerned primarily with the physical theories of planetary motion and Newtonian mechanics, general relativity, and quantum mechanics. Why do we single these out of the myriad of scientific theories that have been constructed? We focus on them largely for their shock value and the insight we can gain into how physical theories are constructed, proven, disproven, and then finally viewed as being generally correct. Upon their inception, each of the theories mentioned above was received with severe criticisms ranging from "the theory is heretical and contradicts the teachings of the Church" to "it must be wrong because God does not play dice with the universe." The fact that scientific theories can elicit such emotional responses and challenge religious beliefs should tell us at the outset that scientific theories are not simply about science. They are ultimately about how we view the world. They represent a position. They provide a cognitive road map by which we are able to make sense of the physical world. This class focuses on how such a congitive road map is constructed and how do we know that such road maps can and should be trusted.

The cornerstone of a theory's success is its explanatory power. Hence, matters of knowability and truth naturally arise in any analysis of in what theories consist. Of course, questions of knowability and truth are some of the basic questions of philosophy. Questions of this sort are generally viewed as questions in epistemology– that is, questions of how do we know what we think we know. In the context of science, the philosophical questions that are raised generally fall into two categories: 1) epistemological or 2) ontological. The latter category is concerned with what exists or as Quine put it, "On What there is", the title of his famous essay on this topic. Any attempt to answer Quine's question constitutes a study in ontology or metaphysics. For example, whether electrons exist or not is an ontological question. However, how we come to know about the properties of electrons is a question of epistemology. Now this is a very important example. In this building, the seat of solid state physics, it is taken for granted that the electron exists. Why is this view so widely held? As humans, we generally take for granted that an object exists if we can see it touch it or smell it. That is, we appeal to our everyday sense perception to settle questions of existence. This sort of empirical sense-oriented approach fails in the context of electrons because as humans, our band width for perceiving the world has its limits. For example, we cannot hear dog whistles, we cannot see X-rays, and we cannot see electrons. All knowledge we have of these entities is entirely indirect. That is, it comes about by first designing instruments that are capable of acting as a go-between the limits of our senses and the microscopic world. In this context, the outcome of a vast number of scientific investigations point to the existence of a particle with charge $-e$. The fact that we can design reliable technology based on the outcome of such experiments lends credence to our interpretation of the experiments.

But we have to be careful here. While it is certainly reasonable, based on Millikan's oil-drop experiment, now a routine high school experiment, to conclude that an electron is as real as any of us is, such an interpretation is based on a bias. It is based on a bias that when we explore nature scientifically, we are really exploring reality objectively. Experiments are telling us what exists in nature. All we have to do is design the appropriate experiment and we will be able to find out everything that is because what there is exists entirely independently of us. This is the realist view. It purports that an objective reality exists and it is just up to us to go out and find it. Absolute knowledge is attainable of the external world by clever experimentation. Most scientists hold this view to be self-evident. However, it is not the only view that is possible. In philosophy of science, the other view which is highly successful in accounting for scientific knowledge is the instrumentalist view. On this account, only the results of the experiments are viewed as being real. That is, the experimental observations themselves, void of any interpretation, constitute the only brute facts of nature. Whatever interpretation, or scientific theory, we construct later on is just a tool to explain the experimental observations. For example, in the context of Millikan's experiment, the 'electron' is an inferred entity from the experiments. An electron is simply a tool for understanding why the total charge in the oil drop changed by an integer multiple of a fundamental quantity, namely e. In this context, instrumentalists remain agnostic as to the existence of an electron. For them, the only thing that exists is the experimental observation not the theoretical constructs that are devised later to help us comprehend what is observed. Hence, on this view, experiments cannot answer those nettling questions in ontology of what exits. They can only provide us with data from which we can construct a cognitive map which we use to understand the physical world. Note that in both accounts, brute facts exists. Its just that both the theoretical constructs and the experimental observations themselves are viewed as being brute facts in the realist account.

You will have to decide for yourselves which theory you will eventually adopt. Even if you decide as did Hume that the only real knowledge is that based on empirical observation, you will still have to decide between the realist and instrumentalist views. The skeptic view applies generally to everything and hence it is not only scientific propositions that are under attack here. What is under attack here is how it is that we can assert anything at all with any certainty when we rely on inference. I have no answer to this question. And last I checked no one does. In fact, we do not even know that the physical laws will not change tomorrow. But experience tells that they won't and that the endeavor of making sense of the physical world is a venture with unprecedented rewards and surprises. We focus here on the highlights of this journey in so far as it has shaped and reshaped our fundamental conception of 'what there is.'

In trying to construct a theory of 'what there is', we need to remember that there is no agreed-upon way of doing this. I do not think this process is random and irrational as Popper has said, however. In fact, the wide acceptance of a theory is not sufficient grounds for it to be believed. Let us consider several examples of well-known theories which were later debunked.

- The sun goes around the earth

  (debunked by Copernicus, 1543 and postulated earlier by Aristarchus, 250 BCE)

- Bodies on which no forces act come to rest

  (debunked by Descartes, 1640)

- Time is independent of the observer

  (Einstein, 1905)

- The outcome of any experiment is in principle uniquely determined

  (disproved by Heisenberg, 1926)

- The universe is static

  (debunked by Hubble, 1933)

- Nature cannot tell left from right

  (debunked by Yang and Lee, 1956)

- Each spatially separated piece of the world must be describable in its own right

  (debunked by Aspect, 1982)

- Einstein's cosmological constant was his biggest blunder.

  (debunked by Krauss, Perlmutter, 1982)

- Electric charge is always quantized in integer multiples of -e, the fundamental electric charge.

  (Nobel prize, Laughlin, Stormer, Tsui, 1998)

All of these were widely held to be true. The fact that they are no longer believed tells us that they have been shown to be inconsistent with experiments. The ultimate success of a physical theory rests on its compatibility with experimental observations. But this is not the only test. General guidelines for the success of a physical theory are the following: 1) Experimental verification, 2) Consistency with other theories, and 3) Simplicity. Of these, (2) is the most subtle. A theory can either be contained by a larger theory or it can imply other theories. For example, classical mechanics explains bouyancy. However, the correct explanation of buoyancy predated classical mechanics. Nonetheless, it is contained in classical mechanics. Two theories are referred to as being vertically consistent when one can be deduced from the other. Horizontal consistency is also possible. To see how all of this works, we will consider several examples of physical theories and examine how they score on each of these points. The first theory we will consider is the revolution that Copernicus brought on in the 16th Century when he reformulated planetary motion with the sun at the center of our universe. There is only one other theory which has wreaked such far-reaching havoc on our preconceived beliefs– Darwin's theory of evolution. Both elicited monumental frowns from all the usual religious suspects. Nonetheless both theories are true. However, while the state board of Education of Kansas voted to disallow the teaching of Darwin's theory (and if you don't believe this is true check out the NYT August 12, 1999, page 1, coloumn 6) , they have not touched Copernicus' theory yet. In fact, it would be hard to imagine that they would do so. However, in 1542, they would have undoubtedly led the revolt against Copernicus. I close with the prologue to Copernicus's De Revolutionibus: